Activates:
PP1
PP 2A
PDH Phosphatase
Citrate Lyase

Insulin (β-cells)

Glucagon (α-cells)

Activates
Lipases
phosphorylase kinase
FBPase (gluconeogenesis only)

Protein Kinase 1 and Glycogen Phosphorylase Mechanism

nonreducing end
glycogen phosphorylase + pyridoxal 5'-phosphate (PLP)
has half-chair intermediate, inhibited by lactone:
αG1P
half-chair
gluconolactone

Make Glycogen Synthesis and Phosphorylation Regulation
Break
Protein Kinase A
Phosphorylase b Kinase
Phosphorylase b
Phosphorylase a
Synthase a
Synthase b
Phosphoprotein phosphatase 1

Glycolysis NET: 2ATP 4 NADH (anaerobic)

Glucose

① HexoKinase + Mg2+
④ Glucose-6-Phosphatase + Mg2+

Protein Kinase A → +Pi → phosphorylase b kinase → ① Glycogen Phosphorylase (R) (PP1 conv.) → Glycogen

Glycogen → ③ Glycogen Synthase (R) (PP1 conv.) → UDPG

UDP (UDP+ATP ⇌ UTP+ADP) each atp costs 2 ATP

αG1P → ② NDP Sugar Pyrophosphorylase (UTP, (P)i x2) → UDPG

G6P
glucose-6-phosphate

② Phosphoglucomutase
① Phosphoglucomutase
phosphoprotein phosphatase 1

Phase 1 of Pentose Phosphate Pathway (oxidative phase)
① G6P Dehydrogenase (NADP+ → NADPH + H+)
③ 6 phosphogluconolactonase
6-phosphogluconolactone
6 phosphogluconate
③ 6phosphogluconate dehydrogenase (NADP+ → NADPH + H+, CO2)
Ribulose-5-phosphate

② Phosphohexose Isomerization

Fructose
① HexoKinase (not in Liver) (ATP → ADP)
Fructose 6-Phosphate
F6P
PFK-2 (ATP → ADP)
FBPase-2 (Pi, H2O)
Fructose 2,6 Bisphosphate (turns PFK-1 on) = glycolysis go!
(turns FBPase-1 off) = gluconeogenesis stop!

③ PhosphoFructoKinase-1 + Mg2+ (phosphate to C1 -OH)
③ Fructose-1,6-Bisphosphatase-1 + Mg2+
*inorganic phosphate
fructose 1,6-bisphosphate
F1,6BP

Phase II of Pentose Phosphate pathway non-oxidative phase (No NADPH)
"Stage II"
phosphopentose Isomerase
phosphopentose Epimerase
Ribose-5-Phosphate
Xylulose-5-Phosphate
~or~
Ru5P:Xu5P 1:1

"Stage III"
2 Xylulose-5-phosphate + 1 Ribulose-5-Phosphate → 2 F6P + 1 GAP
2 Enzymes - Transaldolase, Transketolase
Requires 3 G6P to go thru stages I and II

from triacylglycerides
① glycerol Kinase (ATP → ADP)
glycerol
glycerol-3-phosphate
③ glycerol-3-phosphate dehydrogenase (NAD+ → NADH + H+)

Fructose
① Fructo Kinase (liver) (ATP → ADP)
Fructose-1-Phosphate
② Fructose-1-phosphate aldolase
⑤ Triose Phosphate Isomerase
DHAP
⑨ Aldolase
glyceraldehyde
③ Triose Kinase (ATP → ADP)
GAP
⑥ GAP Dehydrogenase oxidation (NAD+, Pi → NADH)
1,3-bisphosphoglycerate
1,3BPG
⑦ Phosphoglycerate Kinase + Mg2+ (ADP → ATP)
3-phosphoglycerate
3PG
⑧ Phosphoglycerate Mutase
2-phosphoglycerate
phosphate allows for high-tension molecule to exist (PEP)
⑨ Enolase (H2O)
Phosphoenol Pyruvate (PEP)
Phosphate traps it in PEP
release of CO2 makes this favorable
② Phosphoenol Pyruvate Carboxy Kinase (GDP, CO2 → GTP)
⑩ Pyruvate Kinase Mg2+ K+ (ADP → ATP, Removed ions)
Pyruvate
Active transport

Glycolysis NET: 2ATP 4 NADH (anaerobic)

Gluconeogenesis

Oxaloacetate (OAA)
Malate Dehydrogenase (NAD+ → NADH + H+)
Malate
Active transport
Malate dehydrogenase (NADH + H+ → NAD+)
Malic Enzyme (CO2, NADPH + H+, NADP+)

Aerobic Fermentation
Lactate
Lactate dehydrogenase (liver)
Pyruvate
Lactate dehydrogenase (muscle)
Ethanol
alcohol dehydrogenase
Acetaldehyde
(yeast) Pyruvate decarboxylase (CO2, TPP, H+)

Mitochondria

* inorganic phosphate product
① Pyruvate Carboxylase + Biotin Cofactor (HCO3-, ATP → ADP, Pi)
Oxaloacetate (OAA)
malate dehydrogenase
Malate
Pyruvate
① Pyruvate dehydrogenase Complex (PDC) (NAD+ → NADH + H+, CO2)
* Acetyl-CoA
acetyl-CoA cannot enter gluconeogenesis

Citrate Transporter

Export to cytoplasm
② Citrate Synthase (H2O → CoASH)
① Citrate Synthase
Oxaloacetate
Citrate
Liver and Adipose tissues
Fatty Acid Synthesis
* when ATP is high, storing Acetyl-CoA for later

TCA
Can I Keep Selling Sex For Money Officer
Citrate
Isocitrate
α-Ketoglutarate
Succinyl CoA
Succinate
Fumarate
Malate
Oxaloacetate

② Aconitase (H2O)
Isocitrate
④ Iso Citrate dehydrogenase (NAD+ → NADH + H+, CO2)
α-Ketoglutarate
⑤ α-Ketoglutarate dehydrogenase (CoASH) (NAD+ → NADH + H+, CO2)
Succinyl-CoA
⑥ Succinyl-CoA Synthetase (GDP, Pi → GTP)
Succinate
⑦ Succinate dehydrogenase (FAD → FADH2)
Not free-floating
fumarate
⑧ Fumarase (H2O)
L-malate
⑨ Malate dehydrogenase (NAD+ → NADH + H+)
* anti-additional

ODD number of carbons β-oxidation
① Propionyl-CoA Carboxylase + Biotin (HCO3-, ATP → ADP, Pi)
propionyl-CoA
② methyl malonyl epimerase
S-methyl malonyl-CoA
R-methyl-malonyl-CoA
③ methyl malonyl-CoA mutase + Vitamin B12

Fatty Acid Synthesis
Liver and Adipose tissues
* when ATP is high, storing Acetyl-CoA for later
Malonyl-CoA
Acetyl-ACP
(1A) Malonyl-CoA-ACP Transacylase (MAT) (only happen 2x per FA)
priming
Acetyl-CoA
③ Citrate Lyase (ATP → ADP, CoASH)
Citrate
Malonyl-CoA
(1B) MAT adds Malonyl-CoA to ACP
Acetyl-KS
② β Keto Acyl Synthase (KS) (-CO2)
β Keto Acyl-ACP
③ β Keto Acyl-ACP Reductase (KR) (NADP+ → NADPH + H+)
β-Hydroxy Acyl-ACP
④ β Hydroxy Acyl-ACP dehydrase (DH) (H2O)
Enoyl-ACP
⑤ Enoyl-ACP reductase (NADP+ → NADPH + H+)
Acyl-ACP
⑥ KS picks up longer Acyl from MCP
ACP ~SH
Malonyl-ACP
② KS adds Malonyl-ACP to Acetyl group (-CO2)
Steps 3 4 5 again
⑥ KS picks up longer Acyl
⑦ Palmitoyl Thioesterase (TE) removes FA
Palmitate
Etc... until 16C long

Mechanism
Malonyl-ACP → (CO2) → resonance → ACP~S-CH2 → ACP~S-CH2

Fatty Acid Priming and Transport -2ATP
① Acyl-CoA Synthetase (ATP → AMP + PPi, CoASH)
Palmitic Acid
Acyl-CoA
② Fatty Acid CoA Synthetase (ATP → 2ADP, CoASH)
③ Carnitine Transferase I * regulated by malonyl-CoA (Carnitine)
Acyl-Carnitine
④ Carnitine acyl-carnitine translocase

Cytoplasm / Cytosol

Carnitine Acyl-carnitine Translocase

⑤ Carnitine transferase II (CoASH, Carnitine)
Acyl-carnitine
(out) Carnitine
Acyl-CoA
① Acyl-CoA Dehydrogenase Electron Transfer Flavoprotein (ETF) (FAD → FADH2)
Enoyl-CoA
② Enoyl-CoA hydratase (H2O)
β-oxidation
* when glucose is low
L-3-hydroxy acyl CoA
③ hydroxyacyl CoA dehydrogenase (NAD+ → NADH + H+)
β-Ketoacyl CoA
④ β Ketoacyl-thiolase (CoASH)
Enters CAC
Acetyl-CoA
Acyl-CoA (-2Cars)
Thiolase
Ketogenesis
acetoacetyl-CoA
HMGCoA Synthase
β-hydroxy-β-methyl glutaryl CoA

Intermembrane Space
Electron Transport Chain
ATP Synthase
Complex I
Complex II
Complex III
Complex IV
Coenzyme Q (Ubiquinone)
Cytochrome C
Succinate CoA Reductase
CoA-SH, Glutathione
FADH2
NADH
2H+
3H+
4H+
ATP

Mitochondrial Matrix

β-hydroxybutyrate
Acetoacetate
or
Acetone
CO2
To the Brain for energy (during ketosis)

BRAIN
β-hydroxybutyrate dehydrogenase (NAD+ → NADH + H+)
β-hydroxybutyrate
Acetoacetate
Succinyl-CoA
Succinate
-2ATP
acetoacetyl-CoA
3Ketoacyl CoA transferase
Thiolase
Acetyl-CoA + Acetyl-CoA
1 ATP 3 NADH 1 FADH2
2ATP -2 6 NADH +2 2 FADH2
8 NADH 2 FADH2